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UNITED STATES PATENT APPLICATION

FOR

SPACERLESS DIE STACKING

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SPACERLESS DIE STACKING

BACKGROUND

FIELD OF THE INVENTION

[001] Embodiments of the invention relate to the field of semiconductor, and more specifically, to device packaging.

DESCRIPTION OF RELATED ART

[002] Spacers are elements that are used to elevate same or similar sized die that are stacked one above another so that the bond pads on the die below are not covered up. Spacers can be made of various materials including silicon, polymer films, or polymer pastes with filter particles. This adds the elevation (z) height for every spacer that is used resulting in high thickness of the die assembly.

[003] Existing techniques have a number of disadvantages. One method is to thin the wafer. However, there is a limit on how thin the wafer can be. In addition, thinning the wafer may have problems in grinding, polishing, and handling.

BRIEF DESCRIPTION OF THE DRAWINGS

[004] The invention may best be understood by referring to the following description and accompanying drawings that are used to illustrate embodiments of the invention. In the drawings:

[005] Figure 1A is a diagram illustrating a package assembly in which one embodiment of the invention can be practiced.

[006] Figure 1B is a diagram illustrating a pair of adjacent dies in the stack according to one embodiment of the invention.

[007] Figure 2A is a diagram illustrating a cross-sectional view of a stair-case configuration according to one embodiment of the invention.

[008] Figure 2B is a diagram illustrating a top view of a stair-case configuration according to one embodiment of the invention.

[009] Figure 3 is a diagram illustrating a top view of a stair-case configuration in both dimensions according to one embodiment of the invention.

[0010] Figure 4A is a diagram illustrating a cross-sectional view of an alternate staggering configuration according to one embodiment of the invention.

[0011] Figure 4B is a diagram illustrating a top view of an alternate staggering configuration according to one embodiment of the invention.

[0012] Figure 5 is a diagram illustrating a top view of an alternate staggering configuration in both dimensions according to one embodiment of the invention.

[0013] Figure 6 is a flowchart illustrating a process to stack the dies according to one embodiment of the invention.

DESCRIPTION

[0014] An embodiment of the present invention is a technique to stack dies in a die assembly. A plurality of dies are stacked on top of one another in a staggering configuration such that an upper die in a pair of adjacent dies face downward or upward and is displaced by a first distance with respect to a lower die in the pair. The adjacent dies are attached by an adhesive layer between the adjacent dies.

[0015] In another embodiment, an upper die having upper first, second, third, and fourth edges is stacked on top of a lower die having lower first, second, third, and fourth edges such that the upper first edge is displaced from the lower first edge by a first distance. The upper first and third edges are opposite to each other. The lower first and third edges are opposite to each other. The upper die is attached to the lower die by a first adhesive layer deposited between the upper and lower dies

[0016] In the following description, numerous specific details are set forth. However, it is understood that embodiments of the invention may be practiced without these specific details. In other instances, well-known circuits, structures, and techniques have not been shown in order not to obscure the understanding of this description.

[0017] One embodiment of the invention may be described as a process which is usually depicted as a flowchart, a flow diagram, a structure diagram, or a block diagram. Although a flowchart may describe the operations as a sequential process, many of the operations can be performed in parallel or concurrently. In addition, the order of the operations may be re-arranged. A process is terminated when its operations are completed. A process may correspond to a method, a procedure, a method of manufacturing or fabrication, etc.

[0018] Figure 1A is a diagram illustrating a package assembly 100 in which one embodiment of the invention can be practiced. The package assembly includes a substrate 110, a plurality of dies 120_1 to 120_N, a plurality of bond pads 130_1 to 130_K, and a plurality of conductors 140_1 to 140_M.

[0019] The substrate 110 is any suitable substrate made of material such as silicon. The substrate 110 may also be a printed circuit board (PCB). The substrate 110 has a number of bond pads to provide interconnections to the dies. The plurality of dies 120_1 to 120_N form a stack and include dies stacked on top of one another. Each die is an

integrated circuit (IC) or a chip. The number of dies in the stack may be any suitable number, odd or even, depending on the desired height. For example, the number of dies may be 4, 5, 6, 9 or 10.

[0020] Each of the dies has a number of bond pads 130_j's (j = 1,...,K) to provide contact for interconnections. The number of bond pads on each die may vary. When the bond pads are not suitably placed, a redistribution layer (not shown) may be formed to redistribute the interconnection pattern. The conductors 140_k's (i = 1,...,M) connect the bond pads from the dies to the bond pads on the substrate. The conductors 140_k's may be wires or conducting material or paths that form electrical connections between the bond pads.

[0021] The dies in the stack are arranged in a staggering pattern. The staggering configuration may be stair-case in one dimension or two dimensions, or alternate. The staggering configuration allows the adjacent dies to be placed off-center, i.e., adjacent dies are displaced with respect to each other by a distance. The distance is selected so that the conductors connecting the bond pads on the dies to the bond pads on the substrate 110 are separated by a conductor distance to avoid touching or crossing each other.

[0022] By offsetting the dies with respect to one another in the stack, no spacers are needed. The dies in essence act like the spacers themselves. The advantages of offsetting the dies in the stack includes more dies for a given height, reduced assembly time, and increased reliability and yield dues to less interfacing problems.

[0023] Figure 1B is a diagram illustrating a pair 120_k of adjacent dies in the stack according to one embodiment of the invention. The pair 120_k includes an upper die 122 and a lower die 125 and an adhesive layer 127. The stack 120 includes a number of layers having a number of pairs 120_k stacked on top of one another. The number of layers may be odd or even. The upper and lower dies 122 and 125 may have same or substantially similar sizes and/or geometries.

[0024] The upper die 122 has four edges: upper first, second, third, and fourth edges. The upper first and third edges are opposite to each other and the upper second and fourth edges are opposite to each other. Typically, the upper die 122 is square or rectangle. Therefore, the upper first and third edges are parallel to each other and the upper second and fourth edges are parallel to each other.

[0025] Similarly, the lower die 125 has four edges: lower first, second, third, and fourth edges. The lower first and third edges are opposite to each other and the lower second and fourth edges are opposite to each other. Typically, the lower die 122 is square or rectangle. Therefore, the lower first and third edges are parallel to each other and the lower second and fourth edges are parallel to each other.

[0026] The upper die 122 is stacked on top of the lower die 125 such that the upper first edge is displaced from the lower first edge by a first distance d_1. The upper die 122 may also be displaced by any angle with respect to the lower die 125. The stacking may also extended to the other dimension such that the upper second edge is displaced from the lower second edge by a second distance d_2. The adhesive layer deposited between the upper and lower dies 122 and 125 to attach these two dies together. In one embodiment, the adhesive layer is made of an adhesive material such as epoxy and can be filled with non-conductive or conductive particles.

[0027] The upper die 122 and the lower die 125 may be stacked as shown in Fig. 1B, i.e., the bottom surface of the upper die 122 is attached to the top surface of the lower die 125. In another embodiment, the top of the upper die 122 and the top of the lower die 125 may face to each other. In other words, the upper die 122 is turned upside down such that its upper surface is attached to the upper surface of the lower die 125. The two dies can be stacked in any configuration, as long as there is an unobstructed area for the bond pads. This unobstructed area may face upward or downward depending on whether the corresponding die faces upward or downward, respectively.

[0028] For interconnection, the conductors are connected or attached to the bond pads of the dies. For example, upper conductor 142 is attached to the upper bond pad of the upper die 122 and lower conductor 144 is attached to the lower bond pad of the lower die 125. Since the dies are offset to each other by a distance, the upper conductor 142 and the lower conductor 144 are separated by a conductor distance. When the bond pads face downward, the resulting conductor interconnections may provide space efficiency and/or design flexibility for the layout on the substrate surface.

[0029] The stack of dies 120 includes any number of layers including pairs like the pair 120_k stacked on top of one another. Depending on how these pairs are stacked on one another, there are a number of staggering configurations of the entire stack. Examples of these configurations include a stair-case configuration in one dimension, a stair-case

configuration in both dimensions, an alternate staggering configuration in one dimension, and an alternate staggering configuration in both dimensions.

[0030] Figure 2A is a diagram illustrating a cross-sectional view of a stair-case configuration according to one embodiment of the invention. For illustrative purposes, four dies are shown.

[0031] The four dies 120_1 to 120_4 are arranged in a stair-case configuration. In this configuration, the dies are offset by a distance in a stair-case pattern. Between adjacent dies, there is an adhesive layer 127_i's ($i = 1,\ldots,4$) to attach the adjacent dies together. The thickness of the adhesive layer may be 0.001". Since the thickness of the adhesive layer 127_i's is much less than that of a conventional spacer, more dies can be stacked together for the same height. The bottom die 120_1 is attached to the substrate by the same adhesive layer 127_1.

[0032] The conductors 140_1 to 140_4 are representative of conductors connecting the die bond pads to the substrate bond pads. Since the dies are offset by a distance, the conductors 140_1 to 140_4 are also offset by a conductor distance sufficiently large to separate the conductors. The conductors 140_4 and 140_2 are shown beneath the corresponding die 120_4 and 120_2 because these two dies face downward to the respective lower dies. The dies are stacked in pairs by having the two dies in each pair face to each other, i.e., their upper surfaces are attached by the adhesive layer. As shown in Fig. 2A, dies 2 and 4 120_2 and 120_4 are turned upside down so that the exposed bond path faces downward.

[0033] Figure 2B is a diagram illustrating a top view of a stair-case configuration according to one embodiment of the invention. For illustrative purposes, four dies are shown.

[0034] The dies are offset by a distance d_1. The distance d_1 may be the same or different for each pair of adjacent dies. In addition, the distance d_1 may be constant or variable depending on the relative orientation of the two adjacent dies. The conductors 140_j's connect the bond pads of the dies on the stair-case side of the stack.

[0035] Figure 3 is a diagram illustrating a top view of a stair-case configuration in both dimensions according to one embodiment of the invention. For illustrative purposes, four dies are shown.

[0036] In this configuration, the dies are offset in both directions or dimensions by distances d_1 and d_2. The conductors connect the bond pads on both stair-case sides of each die to the bond pads of the substrate. As in Figure 2B, the dies 120_2 and 120_4 face toward their respective lower dies, i.e., die 120_1 and 120_3, respectively. The conductors 140_2 and 140_4 are connected to the bond pads on the dies 120_2 and 120_4 facing downward.

[0037] Figure 4A is a diagram illustrating a cross-sectional view of an alternate staggering configuration according to one embodiment of the invention. For illustrative purposes, four dies are shown.

[0038] In this configuration, the dies 120_1 to 120_4 are arranged in a zigzag or alternate pattern. Dies form in pairs of adjacent dies. The dies may face together in the same direction or in opposite directions. In each pair, the upper die is offset from the lower die by a distance. The pairs are then stacked onto one another in alignment, resulting in an alternate staggering pattern. For example, dies 120_1 and 120_3 are aligned and dies 120_2 and 102_4 are aligned.

[0039] In another embodiment, in each pair, the dies may face toward each other, i.e., the upper die is turned upside down as discussed above.

[0040] The conductors 140_j's are connecting the bond pads in both sides of the dies. On one side, the conductors 140_j's connect the bond pads of the lower dies in the pairs to one side of the substrate. On the other side, the conductors 140_j's connect the bond pads of the upper dies in the pairs to the other side of the substrate.

[0041] Figure 4B is a diagram illustrating a top view of an alternate staggering configuration according to one embodiment of the invention. For illustrative purposes, four dies are shown.

[0042] In this top view, only the upper pair is visible showing the dies 120_3 and 120_4. The lower pair including the dies 120_1 and 120_2 are hidden as viewed from the top. The conductors are shown to connect the bond pads of the dies to the bond pads of the substrate on both opposite sides of the stack of dies.

[0043] Figure 5 is a diagram illustrating a top view of an alternate staggering configuration in both dimensions according to one embodiment of the invention. For illustrative purposes, four dies are shown.

[0044] In this configuration, the dies are arranged in the alternate staggering pattern in both directions or dimensions. As seen from the top, only the upper pair is visible showing the dies 120_3 and 120_4. The lower pair including the dies 120_1 and 120_2 are hidden as viewed from the top. The conductors are shown to connect the bond pads of the dies to the bond pads of the substrate on all four sides of the stack of dies.

[0045] Figure 6 is a flowchart illustrating a process 600 to stack the dies according to one embodiment of the invention.

[0046] Upon START, the process 600 determines if there are bond pads on the die at the exposed edges for interconnections (Block 610). If not, the process 600 deposits redistribution layer to re-arrange the bond pads to suitable locations (Block 620) and then goes to Block 630. Otherwise, the process 600 deposits an adhesive layer on the lower die to attach the lower die to the upper die (Block 630). The adhesive layer is deposited to cover sufficient surface areas between the two dies. Next, the process 600 stacks an upper die on top of a lower die such that the upper first edge is displaced from the lower first edge by a distance (Block 640). The upper and lower dies may have the geometry as shown in Figure 1B. The upper die may face upward or downward with respect to the lower die.

[0047] Then, the process 600 attaches the upper and lower conductors to the upper and lower bond pads of the upper and lower dies, respectively, such that the conductors are separated by a conductor distance (Block 650).

[0048] Next, the process 600 attaches the bottom die in the stack to the substrate by an adhesive layer (Block 660). Then, the process 600 stacks dies on top of one another in one of a stair-case and alternate staggering configurations (Block 660) and is then terminated. The staggering or displacement of the dies may be parallel to a die edge or approximately diagonal to a die edge.

[0049] While the invention has been described in terms of several embodiments, those of ordinary skill in the art will recognize that the invention is not limited to the embodiments described, but can be practiced with modification and alteration within the spirit and scope of the appended claims. The description is thus to be regarded as illustrative instead of limiting.